Diffusion in Isotopically Controlled Silicon-Germanium

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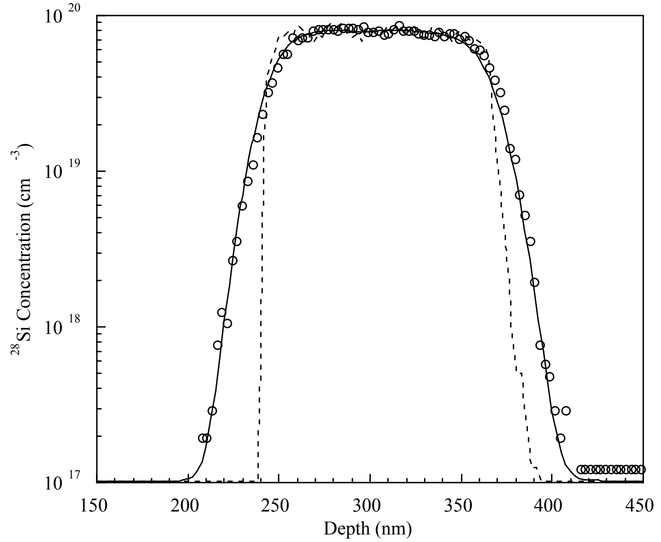
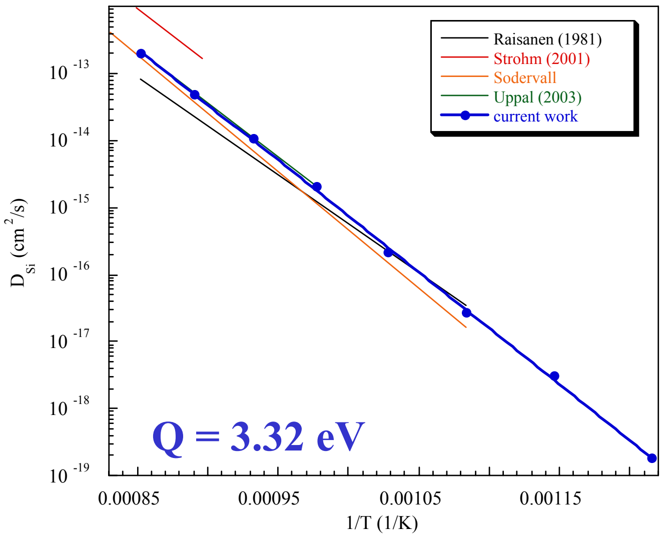
Controlling the diffusion of dopant atoms within advanced semiconductor material systems at the nano scale is necessary for the development of future electronic devices. Crystalline Silicon-Germanium (c-SiGe) is a highly promising semiconductor alloy exhibiting superior electronic transport properties, i.e., higher speed than is offered by current silicon devices. As a first step in our research on diffusion in isotopically controlled c-SiGe and to set a baseline, we have determined the activation energy and temperature dependence of the diffusion of Silicon in crystalline Germanium from computer model fitting of the experimental data.





Above Right: Secondary Ion Mass Spectrometry (SIMS) depth profile of the as-grown Si in Ge (dashed line) and after heating at 550 °C for 30 days (circles). Solid line is the computer model fit to the data.

Right: Plot of the diffusion coefficient vs. inverse temperature yielding the activation energy for diffusion, Q, in comparison to previous work shown.

Diffusion is a fundamental physical phenomenon resulting from the random motion of atoms. Modern electronic devices consist of discrete regions of a wide range of materials. The dimension of these discrete regions is on the order of nanometers (1 billionth of a meter). In order for the electronic device to work properly the different materials that make up the device must remain in the appropriate nanometer-scale regions. Any diffusion which occurs among the different materials in the different regions will hurt the device performance. Therefore understanding the properties of diffusion in the materials that make up modern electronic devices is very important. We are studying the diffusion properties of the Silicon Germanium alloy system. The Silicon Germanium alloy is a material made up of a combination of the semiconducting elements, Silicon and Germanium. We have studied the diffusion of Silicon in pure Germanium and will study the diffusion of the two materials over the entire composition range of the alloy.

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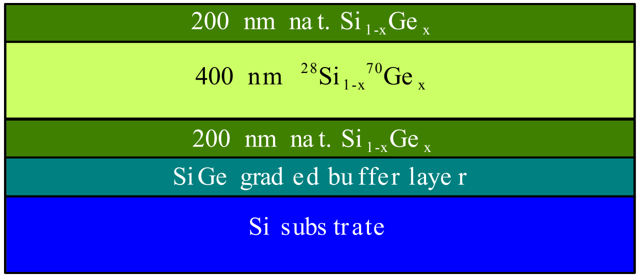
Education:

Four graduate students - Sam Nicols, Cynthia Nelson, Hughes Silvestri, and Chris Liao, along with one undergraduate - Ian Sharp, and one post-doc - Hartmut Bracht contributed to the diffusion research supported by this NSF grant. Sam Nicols received his M.S. degree from UC-Berkeley and is currently working in Sweden. Hughes Silvestri received his Ph.D. from UC-Berkeley and is continuing this research as a post-doc. Hartmut Bracht is a professor at the University of Münster, Germany. Ian Sharp, who was an undergraduate on this project, is currently a graduate student at UC-Berkeley in our group focusing on the nanocrystal portion of this NSF grant.



A diagram of the structure for measuring the simultaneous diffusion of Si and Ge in $Si_{1-x}Ge_x$ alloys. The alternating natural and isotopically enriched MBE-grown layers allow for the observation of Si and Ge diffusion from the natural layers into the enriched layer.

Broader impact:

Fundamental research into new semiconductor materials systems will enable the incorporation of the new materials into modern electronic devices which will lead to faster devices and improved device performance. Our research group is an active member of a university-semiconductor industry collaboration on Small Feature Reproducibility and Feature Level Compensation and Control, whose goal is the development of enhanced control of semiconductor processing.